UM1477
User manual

STEVAL-IFN004V1: BLDC six-step motor drive based on the L6230 and STM8

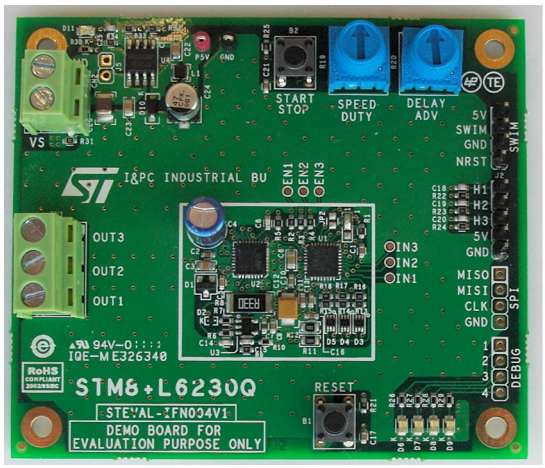
Introduction

The STEVAL-IFN004V1 is a demonstration board based on STMicroelectronic's STM8S105K4 microcontrollers and the DMOS fully integrated 3-phase motor driver L6230 implementing a trapezoidal control (6-step) for a brushless direct current motor (BLDC) in both sensor and sensorless configurations.

It is designed as an evaluation environment for motor control applications in the range of 8 V - 48 V of DC bus voltage (which is extendable up to 52 V) and nominal power up to 35 W using the STM8S105K4 microcontroller with internal 16 kB Flash and the L6230 DMOS driver with 2.8 A output peak current, non-dissipative overcurrent detection/protection, cross conduction protection, uncommitted comparator, thermal shutdown, and undervoltage lockout.

With dedicated hardware evaluation features, the STEVAL-IFN004V1 board is designed to help developers evaluate the device and develop their own applications.
The STEVAL-IFN004V1 can be used together with the STM8 BLDC firmware library v1.0 and constitutes a complete motor control evaluation and development platform.

Figure 1. Image of the board



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1 Main features

The characteristics of the STEVAL-IFN004V1 BLDC 6-step driver board are the following:

- DC voltage range from 8 V to 48 V (extendable up to 52 V)
- Maximum load current of 1.4 Ar.m.s. (2.8 A peak) for each output
- Integrated DC-DC regulator (5 V)
- Monolithic power stage in QFN package featuring overcurrent and thermal protections
- Single shunt current sensing
- Control interface through trimmer and buttons
- Debug outputs
- Hall sensor/encoder inputs
- Optimized layout on 4-layer board for high thermal performance.

1.1 Target applications

The demonstration kit is designed to fit all typical low-power BLDC motor applications, for example:

- Cooling fans
- Pumps

2 Electrical characteristics of the board

Table 1. STEVAL-IFN004V1 electrical characteristics

Parameter	Description	Value	Unit
$V_{S, Max}$	Maximum motor supply voltage	48 (1)	V
$V_{S, Min}$	Minimum motor supply voltage	8	V
I_{out}	Maximum output current	1.4	$A_{r.m.s.}$
$I_{out, peak}$	Maximum output peak current	2.8	A
$T_{j, op}$	Operating temperature	-25 to +125 °C	°C

1. Extendable to 52 V, refer to *Section 4.1*.

3 Schematic, layout, and bill of material

Figure 2. STEVAL-IFN004V1 schematic - MCU, power stage, and current sensing circuitry

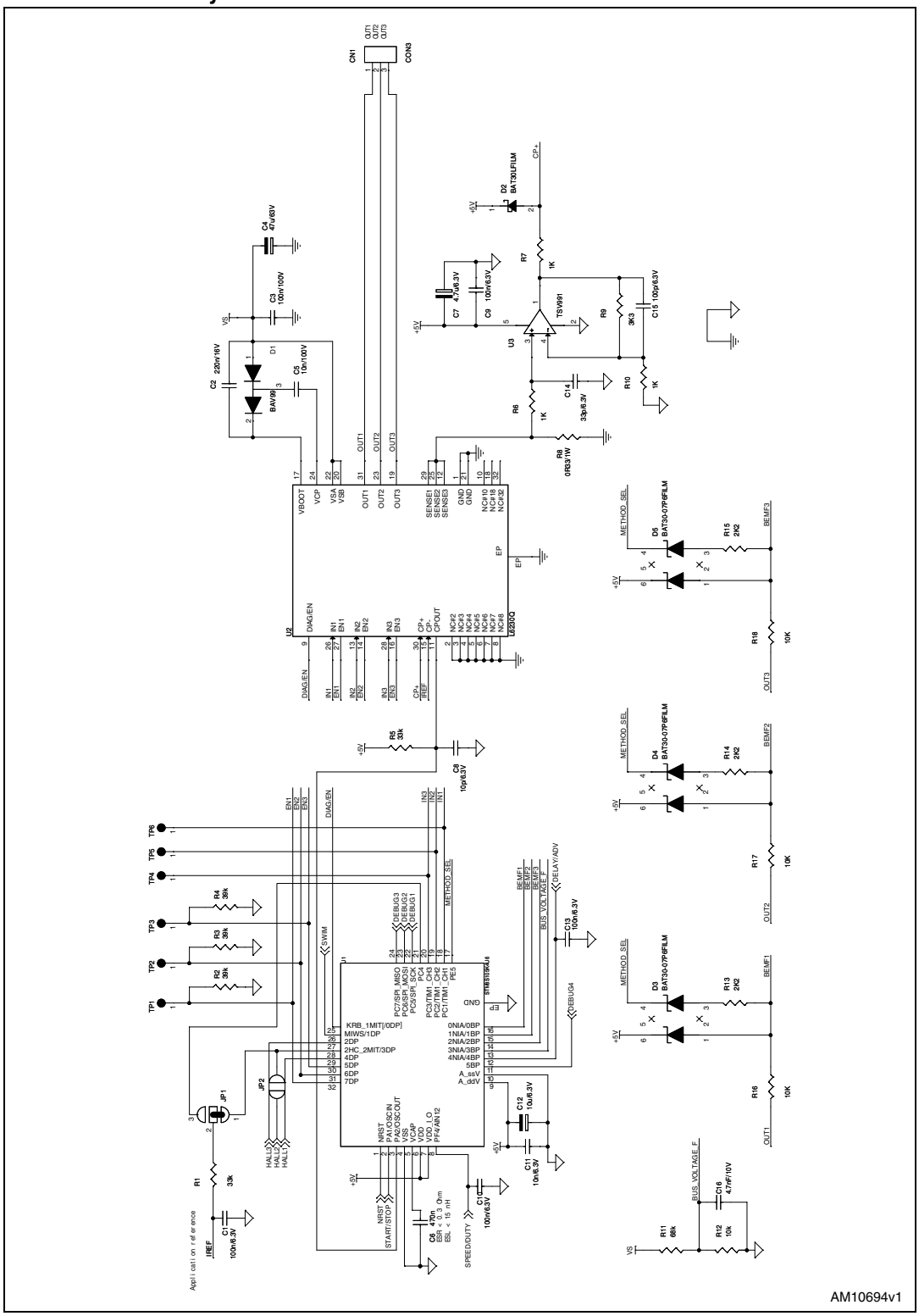


Figure 3. STEVAL-IFN004V1 schematic - power supply

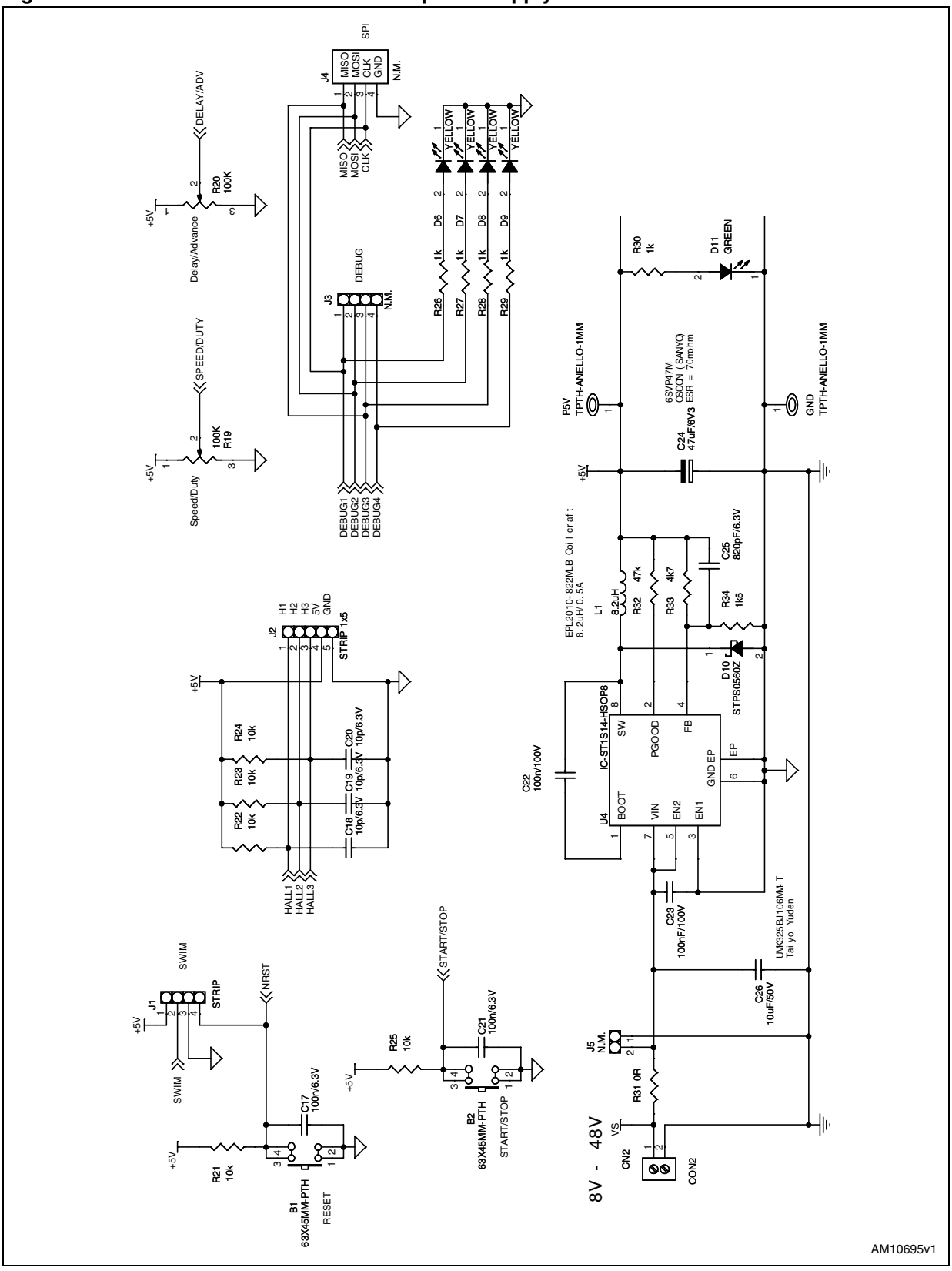


Figure 4. STEVAL-IFN004V1 board layout - top and inner 1 layer

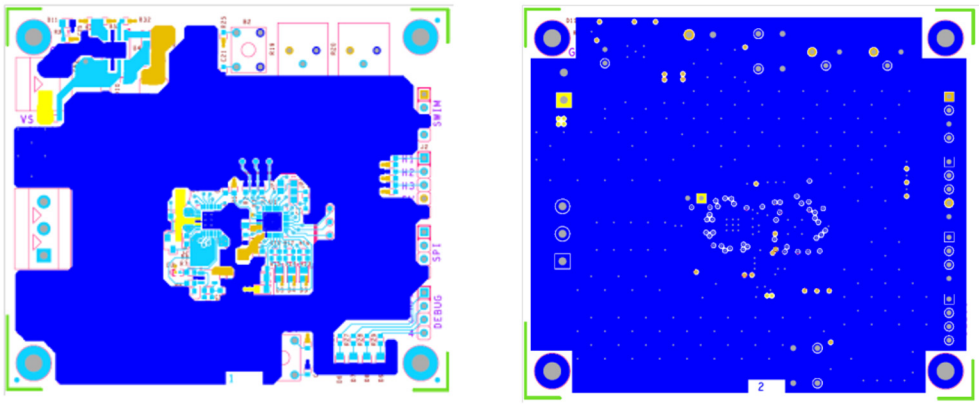


Figure 5. STEVAL-IFN004V1 board layout - bottom and inner 2 layers

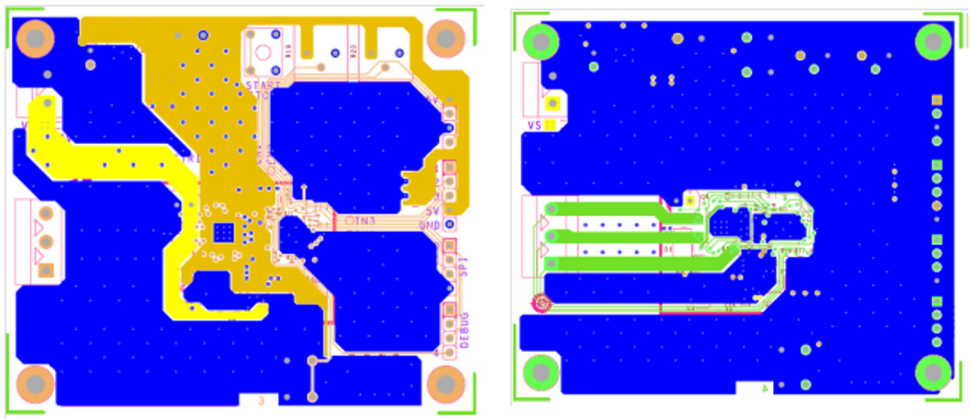


Table 2. STEVAL-IFN004V1

Reference	Part/value	Manufacturer	Manufacturer code
B1, B2	Button 63 x 45 mm		
CN1	3-wire power connector		
CN2	2-wire power connector		
C1, C9, C10, C13, C17, C21	100 nF/6.3 V		
C2	220 nF/16 V		
C3	100 nF/100 V		
C4	47 µF/63 V		

Table 2. STEVAL-IFN004V1 (continued)

Reference	Part/value	Manufacturer	Manufacturer code
C5	10 nF/100 V		
C6	470 nF		
C7	4.7 µF/6.3 V		
C8, C18, C19, C20	10 pF/6.3 V		
C11	10 nF/6.3 V		
C12	10 µF/6.3 V		
C14	33 pF/6.3 V		
C15	100 pF/6.3 V		
C16	4.7 nF/10 V		
C22, C23	100 nF/100 V		
C24	47 µF/6.3 V		
C25	820 pF/6.3 V		
C26	10 µF/50 V		
D1	BAV99		
D2	BAT30	STMicroelectronics	BAT30LFILM
D3, D4, D5	BAT30 (dual parallel)	STMicroelectronics	BAT30-07P6FILM
D6, D7, D8, D9	Yellow LED diode		
D10	STPS0560Z	STMicroelectronics	STPS0560Z
D11	Green LED diode		
J1	Strip line 1 x 4		
J2	Strip line 1 x 5		
J3, J4	Strip line 1 x 4 (N.M.)		
J5	Strip line 1 x 2 (N.M.)		
JP1	Jumper SMD 3 x 1		
JP2	Jumper SMD 2 x 1		
L1	8.2 µH – 0.5 A	Coilcraft	EPL2010
R1, R5	33 kΩ		
R2, R3, R4	39 kΩ		
R6, R7, R10, R26, R27, R28, R29, R30	1 kΩ		
R8	0.33 Ω – 1 W		
R9	3.3 kΩ		
R11	68 kΩ		
R12	10 kΩ		
R13, R14, R15	2.2 kΩ		

Table 2. STEVAL-IFN004V1 (continued)

Reference	Part/value	Manufacturer	Manufacturer code
R16, R17, R18, R21, R22, R23, R24, R25	10 kΩ		
R19, R20	100 kΩ potentiometer		
R31	0 Ω		
R32	47 kΩ		
R33	4.7 kΩ		
R34	1.5 kΩ		
TP1, TP2	Ring test point		
U1	STM8S105K4	STMicroelectronics	STM8S105K4U6
U2	L6230	STMicroelectronics	L6230Q
U3	TSV991	STMicroelectronics	TSV991AILT
U4	ST1S14	STMicroelectronics	ST1S14PHR

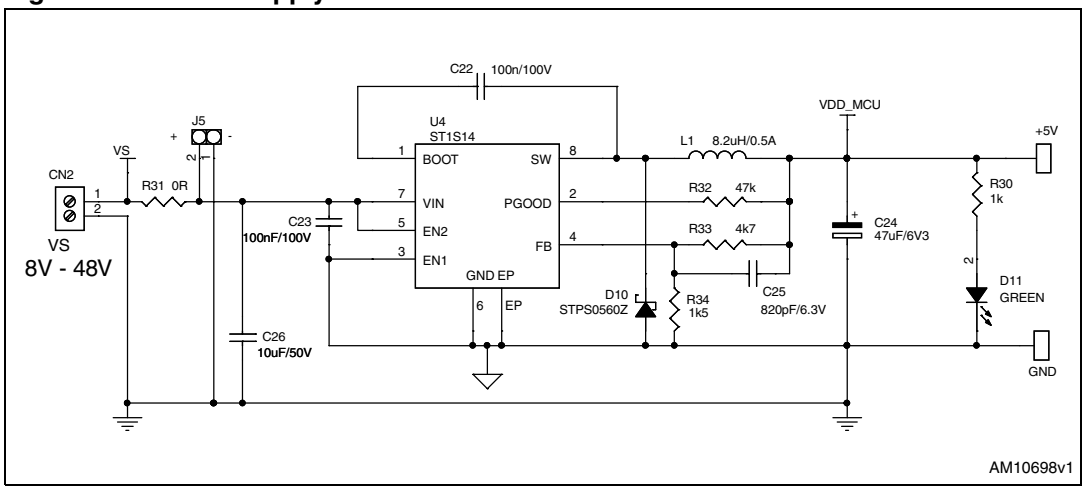
4 General description

4.1 Power supply

The STEVAL-IFN004V1 board is designed to be powered via CN2 connector 'VS'.

The VS supply voltage is used to directly supply the L6230 power stage and is applied at the input of the ST1S14 step-down power switching regulator to generate the 5 V able to supply the microcontroller, the comparator and the board pull-ups (refer to *Figure 6*).

Figure 6. Power supply section



If the system requirements need a power stage supply voltage higher than 48 V (up to 52 V), it is possible to disconnect the switching regulator from the VS connector by removing the R31 resistor and supplying it through the connector J5 to keep generating the 5 V on the board.

4.2 L6230 power stage

The L6230 is a DMOS fully integrated 3-phase motor driver with overcurrent protection. Realized in BCDmultipower technology, the device combines isolated DMOS power transistors with CMOS and bipolar circuits on the same chip.

An uncommitted comparator with open drain output is available (refer to demonstration board schematic in *Figure 2*).

- Features:
  - Operating supply voltage from 8 to 52 V
  - 2.8 A output peak current (1.4 A RMS)
  - $R_{DS(on)}$ 0.73 Ω typ. value @ T_J = 25 °C
  - Integrated fast freewheeling diodes
  - Operating frequency up to 100 kHz
  - Non-dissipative overcurrent detection and protection
  - Cross conduction protection
  - Diagnostic output

– Uncommitted comparator
– Thermal shutdown
– Undervoltage lockout

Figure 7. L6230 block diagram

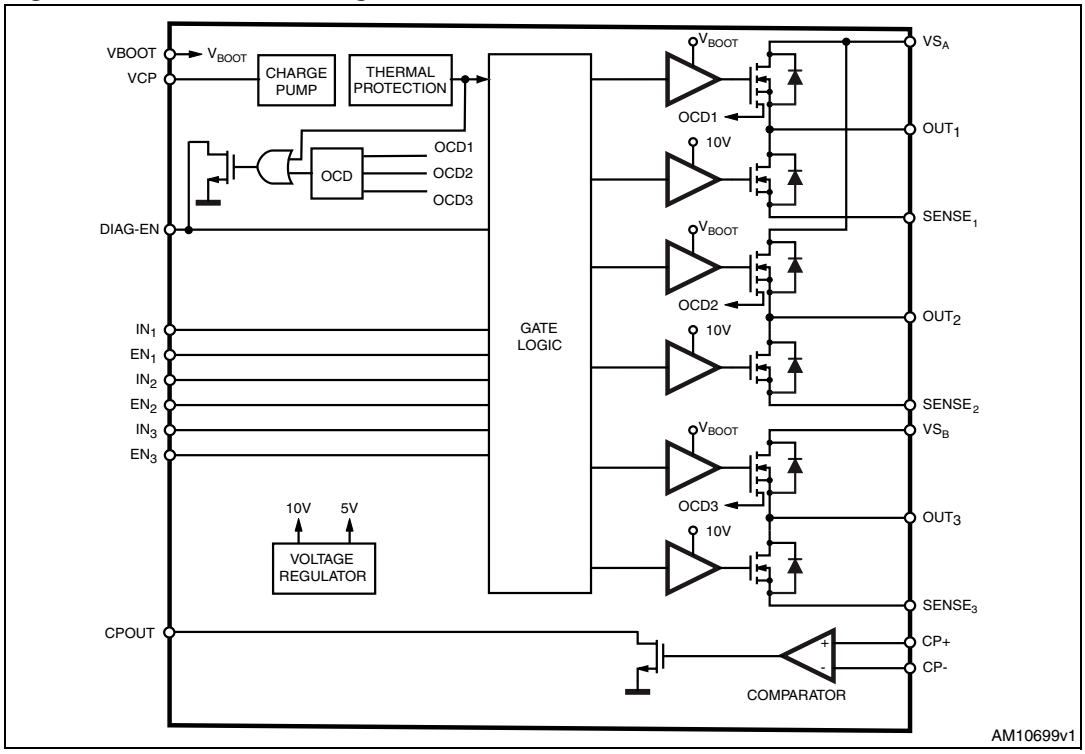


Table 3. L6230 absolute maximum ratings

Symbol	Parameter	Conditions	Value	Unit
V_S	Supply voltage	$V_{SA} = V_{SB} = V_S$	60	V
V_{OD}	Differential voltage between: VSA, OUT1, OUT2, SENSEA and VSB, OUT3, SENSEB	$V_{SA} = V_{SB} = V_S = 60$ V; V_{SENSEx} = GND	60	V
V_{BOOT}	Bootstrap peak voltage	$V_{SA} = V_{SB} = V_S$	V_S +10	V
V_{IN}, V_{EN}	Logic inputs voltage range		-0.3 to +7	V
V_{CP-}, V_{CP+}	Voltage range at CP- and CP+ pins		-0.3 to +7	V
V_{SENSE}	Voltage range at SENSEx pins		-1 to +4	V
$I_{S(peak)}$	Pulsed supply current (for each VS pin)	$V_{SA} = V_{SB} = V_S$; T_{PULSE} < 1 ms	3.55	A
I_S	RMS supply current (for each VS pin)	$V_{SA} = V_{SB} = V_S$	1.4	A
T_{stg}, T_{OP}	Storage and operating temperature range		-40 to 150	°C

Note: Stresses above the limits shown in Table 1 may cause permanent damage to the device.

The L6230 integrates a non-dissipative overcurrent detection circuit (OCD) for full protection.

To implement the overcurrent detection, a sensing element that delivers a small but precise fraction of the output current is implemented with each high side power MOSFET. This current is compared with an internal reference current IREF.

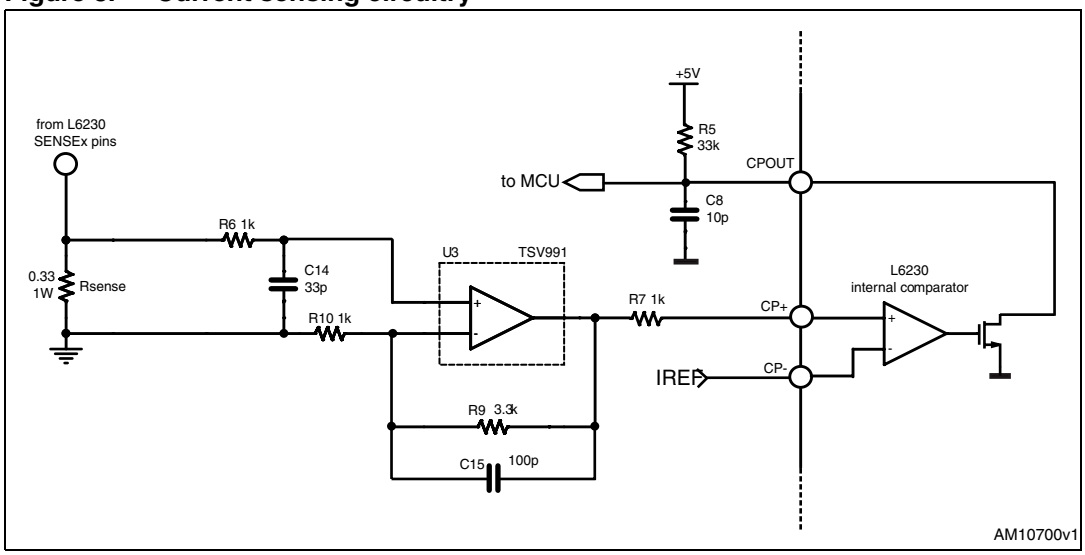
When the output current reaches the detection threshold (typ I_{SOVER} = 2.8 A), the OCD comparator signals a fault condition. When a fault condition is detected, an internal open drain MOSFET connected to pin DIAG-EN is turned on. Pin DIAG-EN is to be used to signal the fault condition to a MCU.

The internal comparator is used for the current control, for more details refer to *Section 4.3* which follows.

4.3 Current sensing circuitry

In the 6-step driving method only one sense resistor is needed, the three SENSE pins are connected together to R_{sense} (refer to *Figure 8*).

Figure 8. Current sensing circuitry



The voltage across the shunt resistor is conditioned by operational amplifiers (TSV991) which provide the proper feedback signals to the non-inverting input of the L6230 internal comparator (CP+ pin). The op amp output voltage range is optimized for a given phase current range and the comparator input dynamics. The op amp output voltage is proportional to the sense voltage; when the CP+ voltage becomes greater than the reference voltage applied at inverting input CP-, the comparator open drain output is switched on pulling down the CPOUT pin.

This signal may be managed by the MCU to generate the proper input sequence for a 6-step driving method with current control and to select what current decay method to implement.

When the CP+ voltage decreases below the CP- voltage, the open drain is switched off and the voltage at the CPOUT pin starts to increase charging the capacitor connected to the pin (C8 in *Figure 2* board schematic).

The reference voltage at pin CP- is set according to the sense resistor value and the desired regulated current.

4.4 Motor position feedback

The MCU must provide the signals to direct the motor rotation and it then requires a means of determining the rotor's orientation/position (relative to the stator coils).

Some designs use Hall effect sensors or a rotary encoder to directly measure the rotor's position. Others measure the back EMF in the undriven phase to gather the rotor position, eliminating the need for separate Hall effect sensors; this method is called sensorless control.

This board is able to manage both Hall effect sensor feedback and back EMF zero-crossing feedback.

Sensored drive

The first method uses position sensors, usually Hall sensors, to measure the rotor position.

Sensorless drive

The other method is based on the BEMF. It analyzes the zero crossing of the floating phase BEMF signal to establish the commutation point. The match between the BEMF signal of the floating phase, with respect to the motor neutral point (or star point), is used to generate the commutation between two consecutive steps in order to achieve rotor synchronization.

More information about the rotor position detection techniques implemented in the STM8 motor control firmware can be found in the UM0708 user manual.

4.5 STM8S105K4 microcontroller

The STM8S105xx access line 8-bit microcontrollers offer from 16 to 32 Kbytes Flash program memory, plus integrated true data EEPROM. They are referred to as medium-density devices in the STM8S microcontroller family reference manual (RM0016).

All devices of the STM8S105xx access line provide the following benefits:

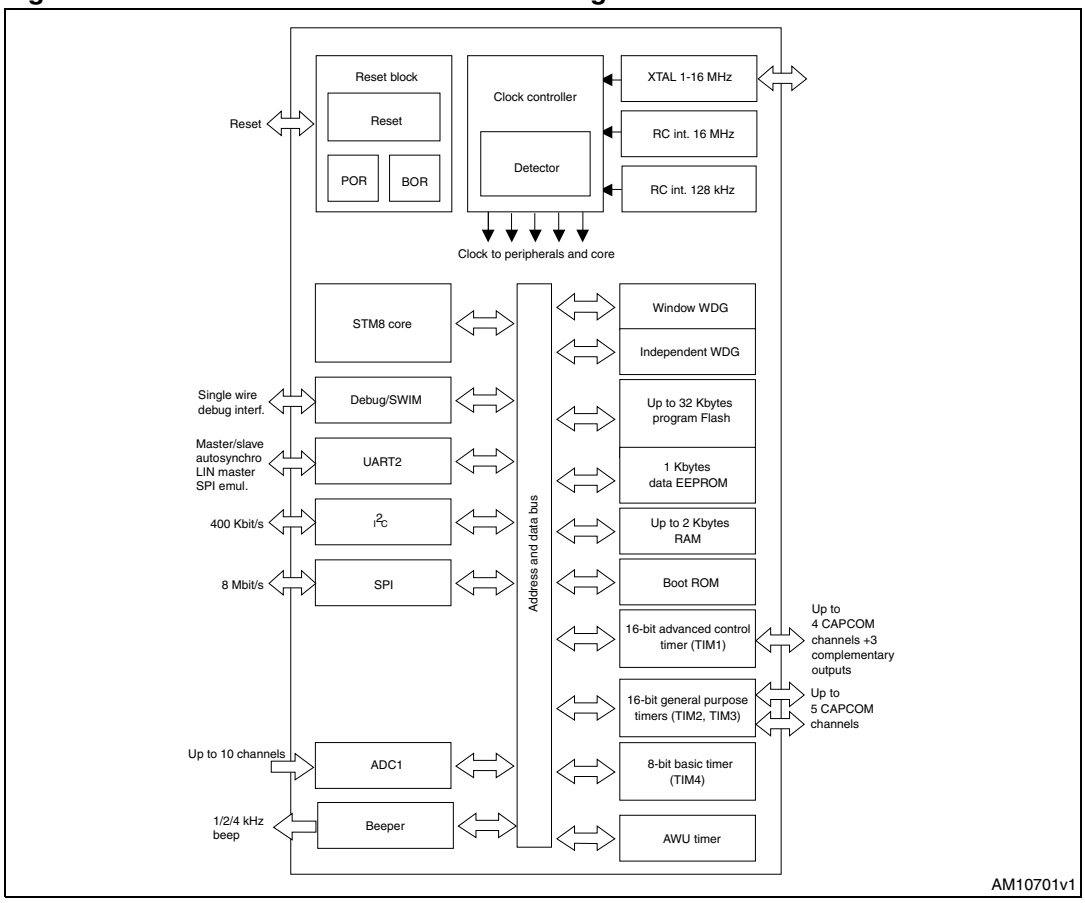
- Reduced system cost
  - Integrated true data EEPROM for up to 300 k write/erase cycles
  - High system integration level with internal clock oscillators, watchdog and brownout reset.
- Performance and robustness
  - 16 MHz CPU clock frequency
  - Robust I/O, independent watchdogs with separate clock source
  - Clock security system.
- Short development cycles
  - Application scalability across a common family product architecture with compatible pinout, memory map and modular peripherals
  - Full documentation and a wide choice of development tools.
- Product longevity
  - Advanced core and peripherals made in a state-of-the-art technology
  - A family of products for applications with a 2.95 to 5.5 V operating supply.

Please refer to the STM8S105xx datasheet for an overview of the complete range of peripherals proposed in this family.

Figure 9 shows the general block diagram of the device family.

It is possible to get more information regarding the feature of the microcontroller and its operating mode in the STM8S-A reference manual.

Figure 9. STM8S105xx access line block diagram



4.6 Using the STEVAL-IFN004V1 with the STM8 BLDC firmware library

The “STM8 BLDC firmware library v1.0” provided together with the STM8-MCKIT performs the trapezoidal control (6-step) of a brushless direct current motor (BLDC) in both sensor and sensorless configurations. It is possible to configure the firmware to work with the STEVAL-IFN004V1 board.

This section describes the customization to be applied to the STM8 BLDC firmware library v1.0 in order for the firmware to be compatible with the STEVAL-IFN004V1.

4.7 Hardware requirements

The following items are required to run the STEVAL-IFN004V1 together with the STM8 BLDC firmware library:

- The STEVAL-IFN004V1 board
- A DC power supply (up to 48 V)
- A programmer/debugger dongle for the control board (not included in the package). To program/debug the STEVAL-IFN004V1, a dongle with single wire debugging capabilities (SWIM) is required. The use of an insulated dongle is always recommended
- A 3-phase brushless motor with permanent magnet rotor (not included in the package)
- An insulated oscilloscope (as necessary)
- An insulated multimeter (as necessary).

4.8 Software requirement

To customize, compile, and download the STM8 BLDC firmware library v1.0, a tool chain must be installed. Please refer to the UM0708 user manual for major details on how to set up the proper tool chain.

Please note that, as is, the STM8 BLDC firmware library v1.0 isn't fully compatible with the STEVAL-IFN004V1.

In order for the STM8 BLDC firmware library v1.0 to be fully compatible with the STEVAL-IFN004V1 it is necessary to install the firmware patch “STEVAL-IFN004V1_Patch.exe” available for download from the ST.com website.

Installing the “STEVAL-IFN004V1_Patch.exe” firmware patch enables the functionality of the “START/STOP” button, of the “SPEED/DUTY” potentiometer and of the “DELAY/ADV”.

Please note that it is not advisable to install the firmware patch in the installation folder of the STM8 BLDC firmware library because the process is not reversible. It is advised to apply the patch in a folder containing a copy of that directory and remember to create a backup copy of that folder before installing the patch.

To summarize, it is possible to follow this guideline:

- Copy the STM8 BLDC firmware installation folder (the default path is “C:\Program Files\STMicroelectronics\STM8MC-KIT v1.0” or similar) including the sub folder in a working folder (example “C:\Working\IFN004V1\”).
- Apply the “STEVAL-IFN004V1_Patch.exe” firmware patch in the working folder (example “C:\Working\IFN004V1\STM8-MC_KIT\”).

4.9 STM8 BLDC firmware library v1.0 customization

To customize the STM8 BLDC firmware library v1.0 for the STEVAL-IFN004V1, use the “STM8S MC FW Library Builder” available for download at the ST.com web site.

The required parameters for the control stage section related to the STEVAL-IFN004V1 are reported in *Table 4*.

Table 4. STEVAL-IFN004V1 STM8S MC FW library builder parameters for the “control stage” section

Block	Parameter	STEVAL-IFN004V1 default value	Unit
Clock	Enable option byte programming	Enabled	
	Frequency	16	MHz
Analog input	Temperature AIN	-	
	Current feedback AIN	AIN10(1)	
	Bus voltage feedback	AIN3	
	Speed potentiometer AIN	AIN12	
	B-emf phase A AIN	AIN0	
	B-emf phase B AIN	AIN1	
	B-emf phase C AIN	AIN2	
	Neutral point	AIN15(1)	
Digital I/O	Debug 0	Port: C pin: 5	
	Debug 1	Port: C pin: 6	
	Debug 2	Port: C pin: 7	
	Debug 3	Port: B pin: 5	
	Dissipative brake signal	-	
	TIM1CHxN re-mapping	-	
	Low side driving signal - phase A	Port: D pin: 5	
	Low side driving signal - phase B	Port: D pin: 6	
	Low side driving signal - phase C	Port: D pin: 7	
Hall sensors	Timer selection	Timer2 Ch2	
	TIM2_CH3 and TIM3_CH1 remapping	Enabled	
B-emf dynamic sampling method selection	Port	E	
	Phase A, pin	5	
	Phase B, pin	6(2)	
	Phase C, pin	7(2)	
	User button port	A	
	User button pin	1	

Table 4. STEVAL-IFN004V1 STM8S MC FW library builder parameters for the "control stage" section (continued)

Block	Parameter	STEVAL-IFN004V1 default value	Unit
User interface	LCD	Disabled	
	Joystick	Disabled	
	Target speed by potentiometer	Enabled	
	Motor auto-start	Disabled	

1. Dummy value.
2. Dummy value.

The required parameters for the power stage section related to the STEVAL-IFN004V1 are reported in *Table 5*.

Table 5. STEVAL-IFN004V1 STM8S MC FW library builder parameters for the "power stage" section

Block	Parameter	STEVAL-IFN004V1 default value	Unit
Rated bus voltage info	Minimum	8	V
	Maximum	48	V
	Nominal voltage	Equal to the BUS voltage provided	V
Power stage	Dissipative brake	Disabled	
Power stage	Bus voltage sensing	Enabled	
Bus voltage sensing	Bus voltage divider	8	
	Temperature sensing	Disabled	
Temperature sensing	V_0	-	mV
	T_0	-	°C
	$\Delta V/\Delta T$	-	mV/°C
	Overtemperature threshold	-	°C
	Overtemperature hysteresis	-	°C
Power stage	HW overcurrent protection	Enabled	
HW overcurrent protection	Comparator threshold	1	V
	Overcurrent network gain	0.35	V/A
	Emergency stop signal polarity	Active low	
	Expected overcurrent threshold	2.8	A
Power stage	Current sensing	Enabled	
Current sensing	Current reading topology	One shunt	
	Shunt resistor(s) value	0.33	Ω
Current sensing	Amplification network gain	4	

Table 5. STEVAL-IFN004V1 STM8S MC FW library builder parameters for the “power stage” section (continued)

Block	Parameter	STEVAL-IFN004V1 default value	Unit
Power switches	Min. dead-time	700	ns
	Max. switching frequency	50	kHz
U,V,W drivers	U,V,W driver high side driving signal	Active high	
	U,V,W driver low side driving signal	-	

5 References

This user manual provides information on the hardware features and use of the STEVAL-IFN004V1 demonstration board. For additional information on supporting software and tools, refer to the following:

1. STM8S105xx datasheet
2. STM8S-A reference manual (RM0016)
3. UM0708 user manual
4. L6230 datasheet
5. ST1S14 datasheet
6. TSV991A datasheet
7. http://www.st.com/mcu/ web site, which is dedicated to the complete STMicroelectronics microcontroller portfolio.

6 Revision history

Table 6. Document revision history

Date	Revision	Changes
21-Dec-2011	1	Initial release.

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